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Inertial response from wind turbines: the impact on structural loads

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Abstract

This works evaluates **the impact on structural loads of DFIG wind turbines providing inertial response** while operating at rated power. The approach is to use an **integrated simulation environment** to model the most important electrical, structural, and control dynamics. Estimation of the impact is done in terms of 1-Hz equivalent loads, and maximum-minimum loads.

Introduction

Inertial response from wind turbines can contribute to maintain short-term stability of the power system. Many manufacturers already offer wind turbines with the capability of providing inertial response, and there are a number of proposed control strategies in the literature. However, grid codes to rule this requirement are not yet in place. *Furthermore, practical implementation of inertial response in variable speed wind turbines may be impose considerable loading on wind turbine components.* This works evaluates the impact on **structural loads** of DFIG wind turbines providing **inertial response** with an integrated simulation approach.

The most important dynamics of power system, electrical machine, control, structure, and aerodynamics are modeled in an **integrated simulation environment**. The software tools integrated in this environment are

1. Aeroelastic software (HAWC2) and
2. Matlab/Simulink.

The integrated model of power system, wind farm and wind turbine is shown in Figure 1. The power system, wind turbine controls and wind turbine aggregation to simulate the wind farm are modeled in Matlab/Simulink while the wind turbine it self is modeled in HAWC2.

Objectives

- Estimate the impact on wind turbine structural loads providing inertial response.
- Compare the response of the power system with, and without inertial response from wind turbines.
- Demonstrate the capabilities of an integrated simulation approach.

Approach

Models developed in Matlab/Simulink are a lumped model of a power system for frequency control (Figure 2), a classical dynamic model of asynchronous machine in dq-frame, its rotor converter control (Figure 3) and a generic blade angle control (Figure 4). These models are coupled to a wind turbine structure, and aerodynamics models in HAWC2 (Figure 3).

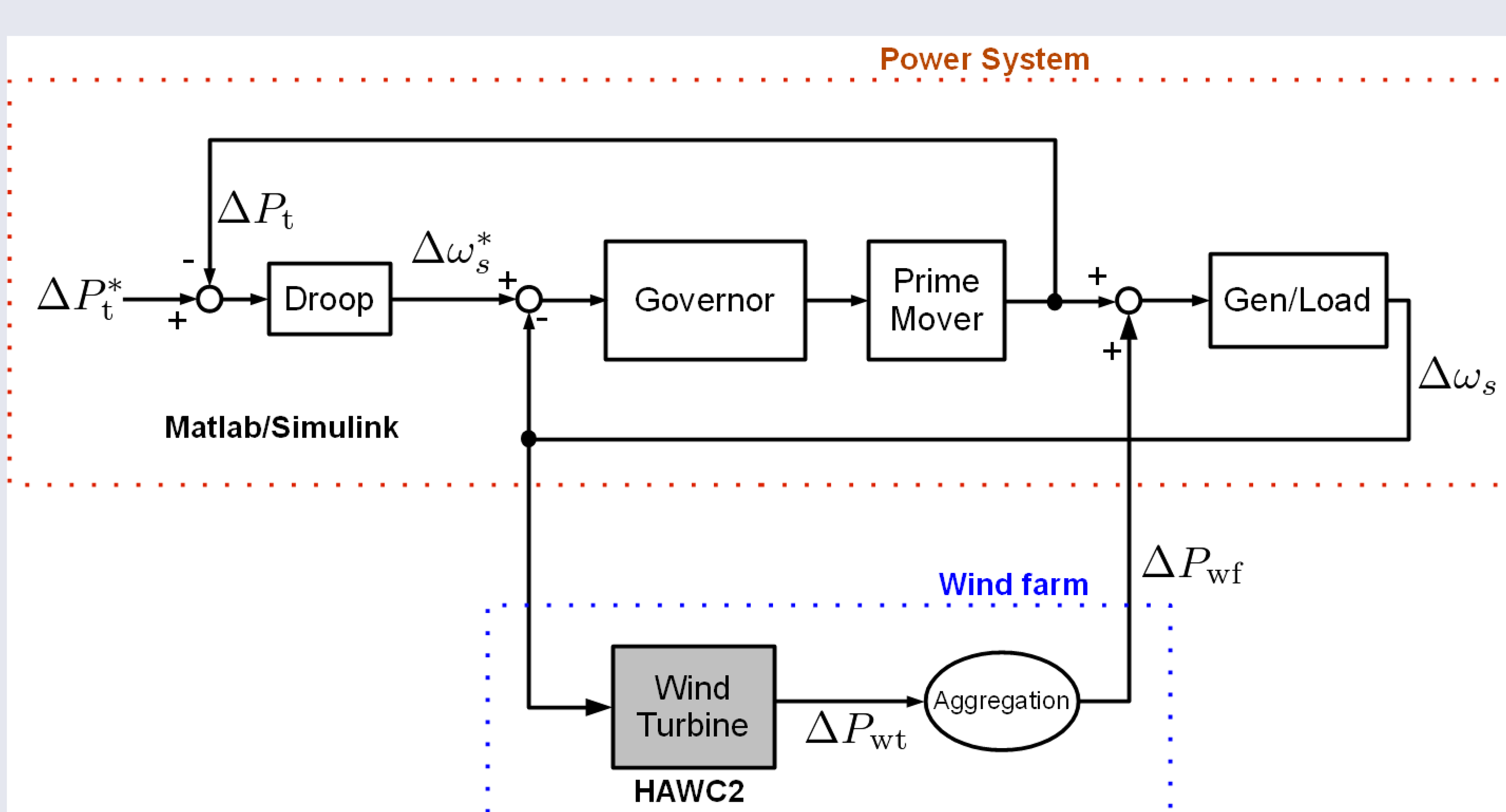

Figure 1. Integrated simulation environment: power system and wind farm model

The power system has a total capacity of 60 MW, a 12 MW wind farm is modeled by aggregating a single 2 MW DFIG wind turbine.

Approach

Two cases are simulated one with the wind farm with inertial response capability producing rated power. The second case without the wind farm. A generic inertia emulation control law from the literature is used (Figure 5). The second case, is used to evaluate the impact on structural loads compared to that of normal operation.

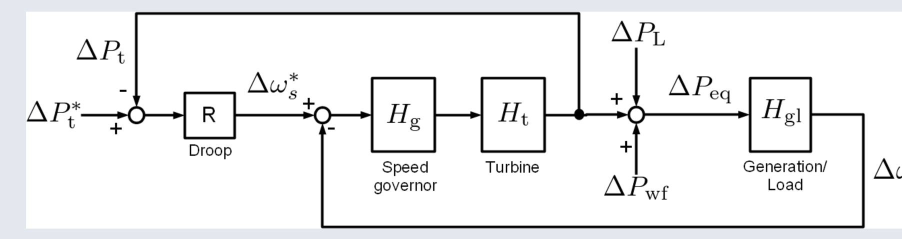

Figure 2. Power system model for frequency control.

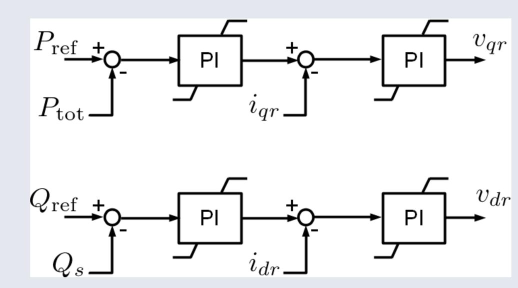

Figure 3. Generic rotor side converter control.

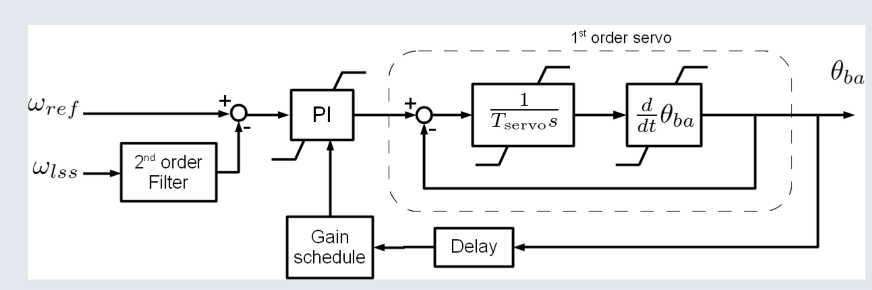

Figure 4. Generic blade angle control.

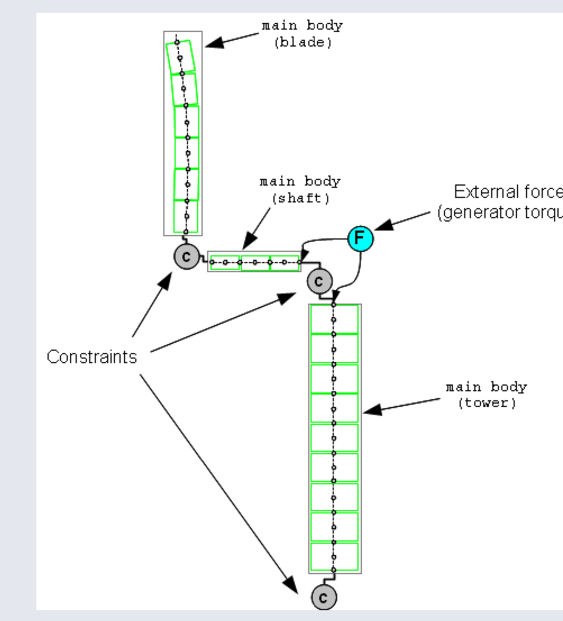

Figure 5. Wind turbine model.

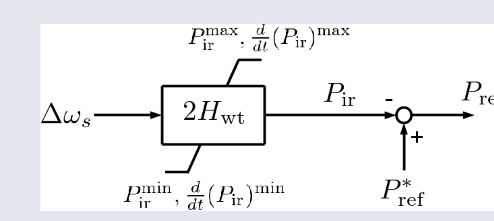

Figure 6. Generic Inertia emulation control.

Results

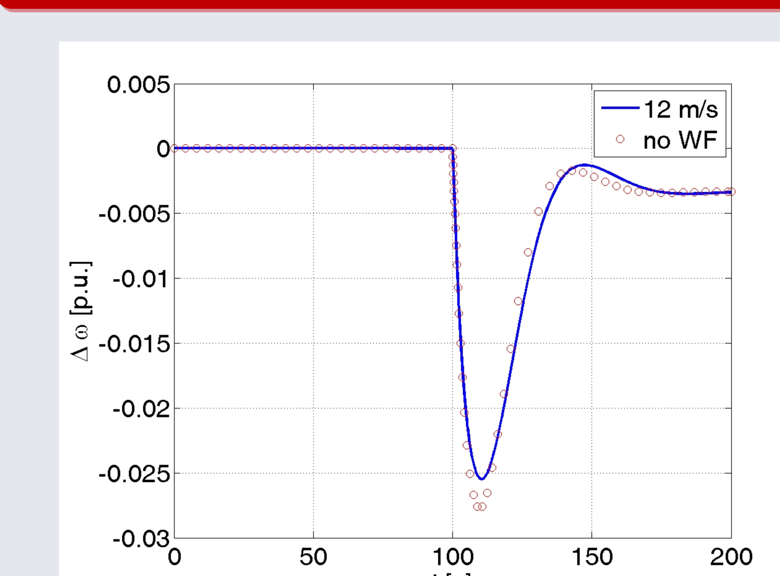

Figure 7. Power system frequency response

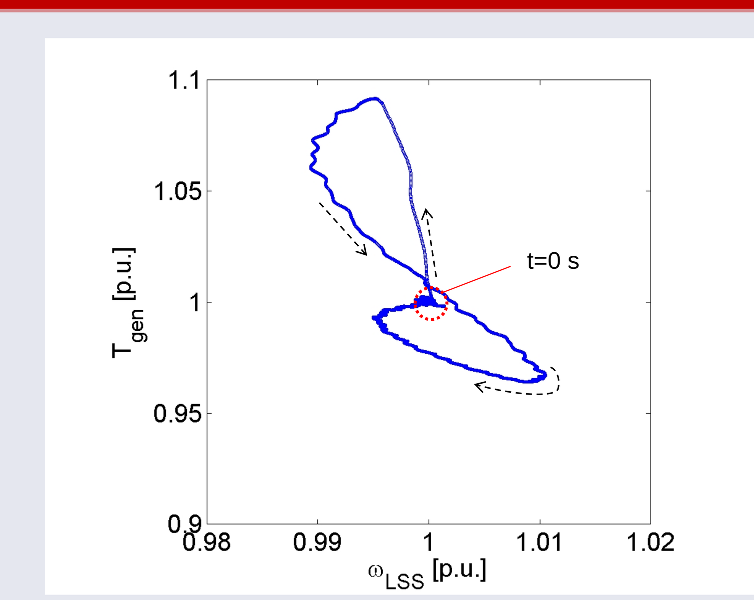

Figure 8. Torque-speed plane

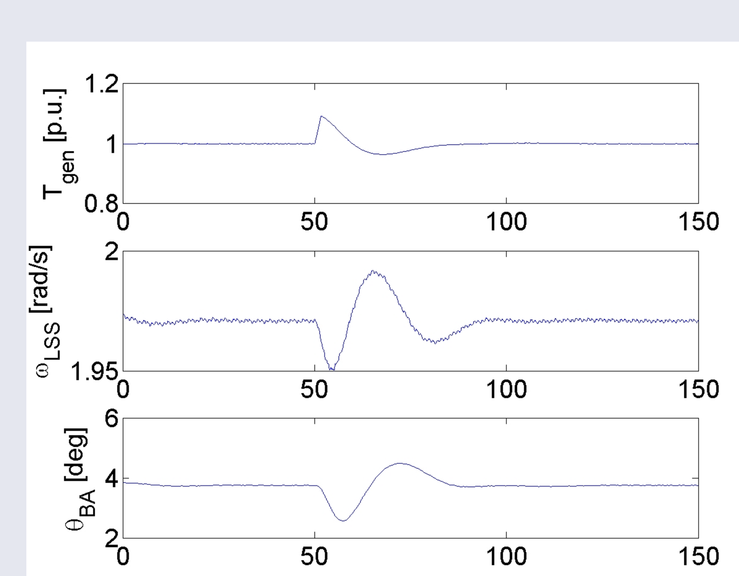

Figure 9. Time response of generator torque, shaft speed and blade angle.

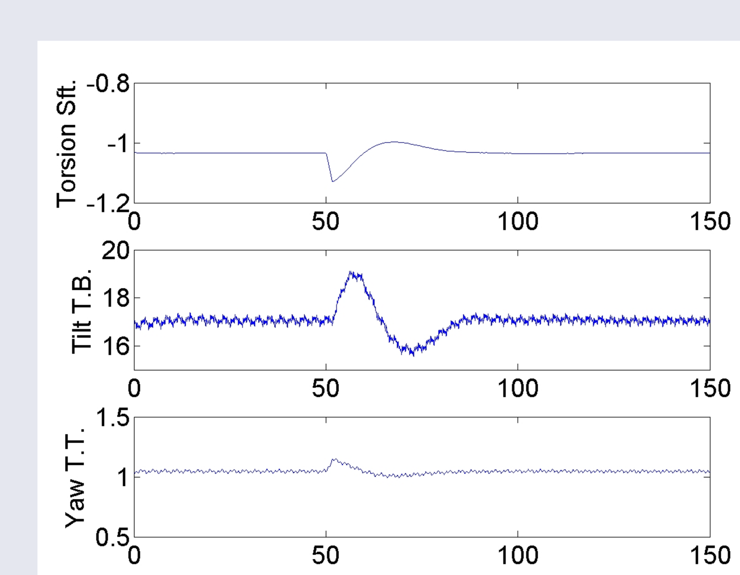

Figure 10. Shaft torsion, tower bottom tilt moment and tower top yaw moment.

Table I. Normalized structural loads

	Shaft			Blade			Tower bottom			Tower top		
	Mx	My	Mz	Mx	My	Mz	Mx	My	Mz	Mx	My	Mz
1-Hz Eq. Load	1.00	1.00	36.85	1.12	1.00	1.08	2.43	1.23	1.00	1.08	2.78	1.01
Maximum Load	1.01	1.01	1.09	1.08	1.03	1.10	1.10	1.09	1.12	1.03	1.08	1.12
Minimum Load	1.00	0.18	0.96	0.92	0.25	0.90	0.93	0.80	0.7	0.96	0.96	0.02
Std. Dev.	1.0	1.00	19.79	1.05	1.0	1.02	4.87	1.24	1.01	1.02	2.6	1.01

Conclusions

The integrated simulation environment and models presented make it possible to assess (1) the impact of wind turbine inertial response on power system frequency while at the same time being able to study (2) the impact on wind turbine structural loads.

Simulations show that in terms of 1-Hz equivalent loads and maximum-minimum loads

- ***shaft torsion*** (top plot Figure 10 / "Shaft Mz" in Table I)
- ***tower bottom tilt moment*** (middle plot Figure 10 / "Tower bottom Mx" in Table I)
- ***tower top yaw moment*** (bottom plot Figure 10 / "Tower top My" in Table I)

in this simulation case are ***significantly affected***. Therefore it is relevant to further study the influence of control parameters, different operating conditions and to take into account the frequency of the event to fully assess the impact on life time.

The trade off between the amount of inertial response that wind turbines can provide, and the cost of the loads imposed on them should be assess from an statistical perspective, and perhaps considered when defining regulations in grid codes.